Transactions of the Royal Society of S. Aust. (1995), **119**(2), 83-88.

CHARACTER AND INTERPRETATION OF THE REGOLITH EXPOSED AT POINT DRUMMOND, WEST COAST OF EYRE PENINSULA, SOUTH AUSTRALIA

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Summary

MOLINA BALLESTEROS, E., CAMPBELL, E. M., BOURNE, J. A. & TWIDALE, C. R. (1995) Character and interpretation of the regolith exposed at Point Drummond, west coast of Eyre Peninsula, South Australia. *Trans. R. Soc. S. Aust.* **119**(2), 83-88, 31 May, 1995.

The weathering mantle developed on granodiorite at Point Drummond, Eyre Peninsula, South Australia is examined using thin section and XRD analyses. Stages in the alteration of the granodiorite can be deduced by examination of the zonation of the regolith: release of oxides and hydroxides from the parent rock; removal of iron and kaolinisation; new concentrations of haematite in micropores; development of nodular structure and renewed removal of oxides and hydroxides. The possible age relationships of this profile with laterites and Plio-Pleistocene ferricretes from other South Australian sites are discussed. The age of weathering is uncertain but it predates the calcarenite (? Pleistocene) and is probably post Permian, with Plio-Pleistocene the most likely.

KEY WORDS: regolith, ferruginisation, Point Drummond.

Introduction

The west coast of Eyre Peninsula is characterised by high cliffs eroded in dune calcarenite (also known as aeolianite: see e.g. Crocker 1946) of Middle and Late Pleistocene age (Wilson 1991[1]). The calcarenite rests unconformably on Precambrian rocks, mostly igneous and metamorphic, with granite and gneiss prominent, but including sandstone and conglomerate near Talia. The unconformity is uneven and the base of the calcarenite commonly extends below sea-level. Elsewhere, the Precambrian basement is exposed in rather irregular shore platforms and in the lower sections of the cliffs which, however, are composed mainly of the calcarenite. At several sites remnants of the pre-calcarenite regolith are developed on the Precambrian basement. One of the best exposures of the regolith, in terms of thickness, completeness and lateral extent, occurs at Point Drummond, a westerly projecting promontory located on the west coast of southern Eyre Peninsula, some 80 km north-west of Port Lincoln (Figs 1 & 2).

The purpose of this short paper is to describe the mineralogical variations between horizons within the regolith, and to discuss their genetic implications. The site is on the southern portion of Point Drummond. Two profiles, one from a south-projecting peninsula and one from the cliff adjacent to the access steps several hundred metres to the north, were examined. The samples were selected on the basis of colour and textural variations. The profiles are so similar both in appearance and upon analysis that they can be treated as one.

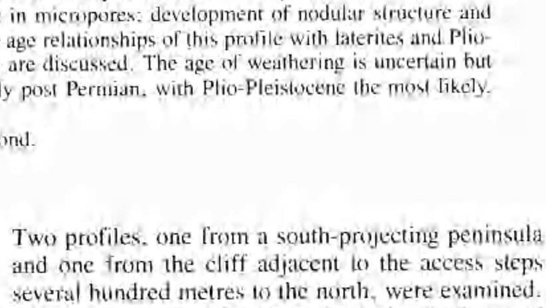

Fig. 1. Location Map.

Description of the profile

The profile, approximately 18 m thick, was subdivided from the base to the top into five horizontal zones on the basis of their colour and texture (Fig. 3). Mineralogy and texture have been studied in thin section (using samples impregnated with a thinned araldite to prevent any disturbance of the original structures) and by XRD analysis of bulk samples.

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[1] WILSON, C. C. (1991) Geology of the Quaternary Bridgewater Formation of southwest and central South Australia. Ph.D. thesis, University of Adelaide, Adelaide (Unpubl).

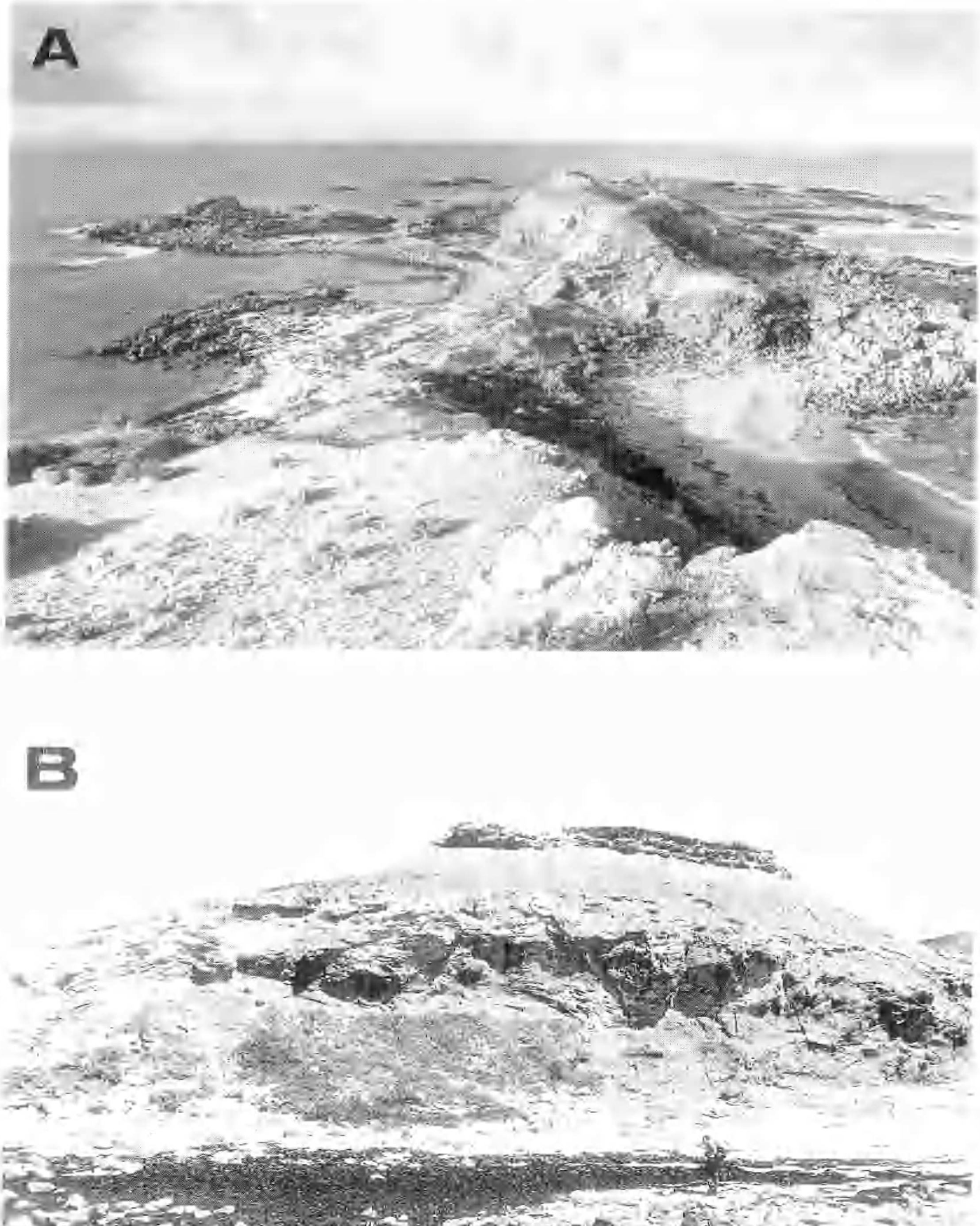

Fig. 2A. General view of Point Drummond, Eyre Peninsula, South Australia. 2B. The weathering profile sample site, Point Drummond peninsula, showing the coastal platform developed in granodiorite, the goethite-rich zone at the base of the cliff and above this the white kaolinised zone, the haematite zone and the calcarenite remnant at the surface.

Zone I

The parent rock is a gneiss of granodioritic composition consisting mainly of quartz, plagioclase, biotite and muscovite with some orthoclase. Secondary minerals resulting from hydrothermal alteration of the rock prior to weathering include sericite, chlorite (from biotite), epidote-zoisite and calcite (from plagioclase - Sample 1, Fig. 3, Munsell Rock Colour N8, white to N3, dark gray - dry. The colours of other samples are Munsell Soil Colours - 1994). The granodiorite is intruded by amphibolitic and quartzitic veins. Schistose shear zones are also present. These various rocks are all members of the Sleaford Complex, dated at 2,700-2,300 Ma and thus of late Archaean or Palaeo-proterozoic age (Flint *et al.* 1984; Parker *et al.* 1985) though the shear zones may result from the Kimban Orogeny (~1700 Ma - Thomson 1969).

Stages in the weathering of the gneiss can be traced by examination of the zonation of the regolith or weathered mantle, assuming that the weathering front, or lower limit of weathering, has descended into the rock mass from the surface. Hence, in these terms, the initial stages of weathering are represented by the zone immediately above the weathering front and the most advanced by the near surface horizon.

The coastal platform eroded in granodiorite and located between high and low tide levels, is irregular with many blocky and bouldery rises and intervening clefts. Many of the outcrops are superficially altered, with rinds of ferruginous oxides and hydroxides developed at the margins of blocks, boulders and other exposures. The rinds are also found bordering fissures (Sample 2, 7.5YR 7/6, reddish yellow to 7.5YR 7/3, pink). In this zone the thickness of the rinds increases up the profile, but nowhere exceeds 5 cm.

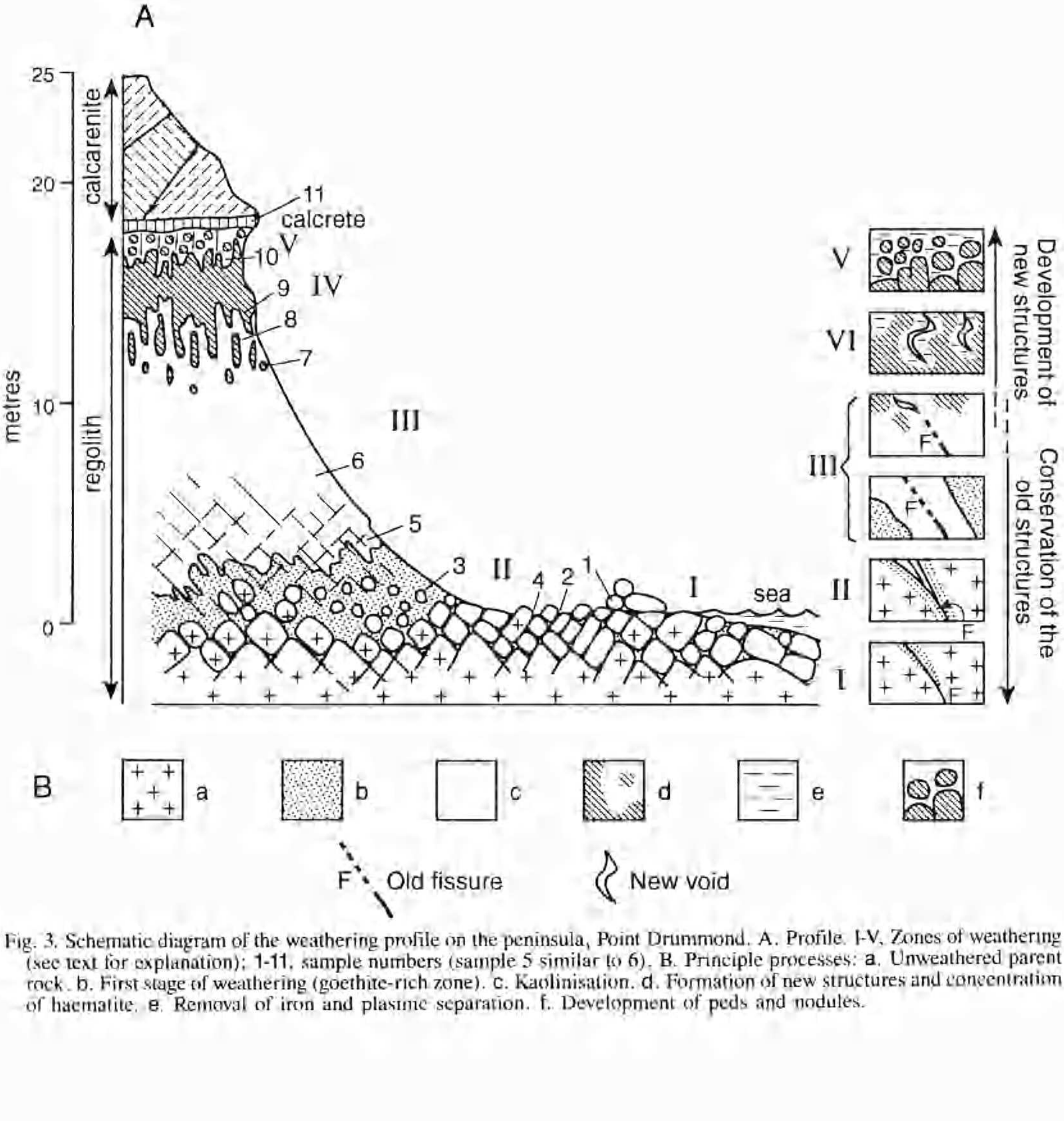

Fig. 3. Schematic diagram of the weathering profile on the peninsula, Point Drummond. A. Profile. I-V, Zones of weathering (see text for explanation); 1-11, sample numbers (sample 5 similar to 6). B. Principle processes: a. Unweathered parent rock. b. First stage of weathering (goethite-rich zone). c. Kaolinisation. d. Formation of new structures and concentration of haematite. e. Removal of iron and plasmic separation. f. Development of peds and nodules.

The first stage of weathering discernible is the development of the rinds around the corestones. In these the epidote-zoisite minerals are dissolved and the alteration of plagioclase is manifested by the appearance of zones of randomly oriented clays. The clay minerals are preferentially developed along fissures presumably because the latter allow penetration of water. Biotite changes colour from green to brownish-yellow, reflecting a release of iron which, as goethite, is concentrated in cracks and fissures.

Zone II

Here, though the original rock structures are everywhere distinguishable, some of the blocks and boulders are entirely discoloured and the rinds are thicker than those in Zone I (Samples 3 & 4, 10YR 8/4, very pale brown to 10YR 7/6, yellow) with a white rind (N8) developed on the outside, and a strong brown (7.5YR 5/6) interior. Again the rind increases in thickness up the profile and, as in Zone I, is also found along partings. The contact between the weathered rind and the interior of the corestones low in the profile is sharp but is more diffuse at higher levels.

The rinds are pale in colour and voids are apparent in thin section. Plagioclase is progressively reduced higher in the profile and essentially isotropic clays, believed to be mainly kaolinite, become dominant. With the XRD method used, it is difficult to differentiate any other polymorphs of kaolin. Resistates such as quartz and muscovite are present.

Zone III

Almost the entire rock in this zone is white (Sample 6, N8) but most of the original textures and structures are preserved and remnants of the yellow and red iron oxides occur as spots in the upper part of the zone. At the top of Zone III loss of material has led to the formation of voids. The weathering plasma (in the sense of Nahon 1991, p. 63), derived from weathering of the parent materials, begins to appear anisotropic, especially in areas close to voids [the vosepic plasma separation of Brewer (1964, 1976)]. Some, though not all, oxide concentrations are related to voids.

Zone IV

The yellow and red spots present in Zone III here merge to give a mixture of oxides and hydroxides of iron in differing degrees of dehydration and crystallisation (Sample 7, 5YR 4/4, reddish brown to 7.5YR 6/8, reddish yellow to 10R 4/3, weak red; Sample 8, 10YR 8/8 yellow to 10R 4/3, weak red; Sample 9, 10R 4/3, weak red to 10R 5/6 red). The zone is up to four metres thick. None of the original structures survives.

XRD analysis shows that haematite is dominant in the weak red patches, kaolinite having been removed. On the other hand, where there is no iron oxide or hydroxide, the kaolinitic alteroplasma is well preserved. Muscovite remains, albeit weathered to varying degrees and quartz is corroded and in some instances clearly disaggregated. At the top of Zone IV voids are common.

This zone is similar to the "mottled clay" horizon from a laterite profile described by Nahon (1987), of which alumina (not analysed in this study) is a typical component.

Zone V

The lower part of this zone is characterised by irregular ill-defined fissures in the mottled clay. Also, a new structure occurs in the form of polyhedral peds some centimetres across. They become smaller and more rounded upwards, where they take the form of soft nodules 0.5-1.0 cm in diameter, reddish yellow in colour but with red oxide concentrations in the interior (Sample 10, 7.5YR 6/6, reddish yellow to 10R 4/6, red) (Fig. 4). The partings which define the polyhedral peds are preferential zones of leaching. Removal of oxides and hydroxides has resulted in zones of concentration of skeletal grains (mainly quartz) from the parent material, and in the appearance of a kaolinitic clay plasma (a pedoplasma in the sense of Boulet 1974). It grades from asepic, where oxyhydroxides are abundant, to skelsepic, vosepic and even masepic where the oxyhydroxides have disappeared (Brewer 1964, 1976). The development of the nodules is a centripetal process involving the removal of oxides and hydroxides from the margins of the peds and their concentration in the nodules, the redistribution of clays and the concentration of skeletal grains in the leached zones.

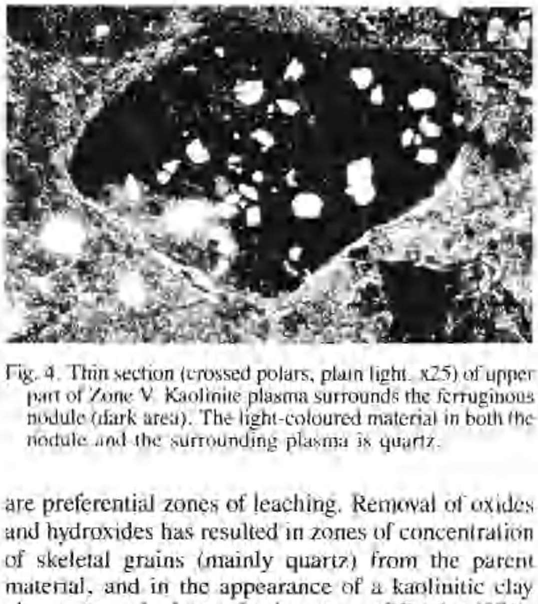

Fig. 4. Thin section (crossed polars, plain light, x25) of upper part of Zone V. Kaolinite plasma surrounds the ferruginous nodule (dark area). The light-coloured material in both the nodule and the surrounding plasma is quartz.

Both the promontory and the cliff profiles are overlain by a calcareous crust (calcrete - Sample 11, 2.5Y 7/2, light gray), located at the base of the calcarenite but developed on the weathered material and including nodules like those found in Zone V (Fig. 3).

Interpretation

Various stages in the weathering of the granodiorite are evidenced:

1. The penetration of meteoric waters from the surface and release of oxides and hydroxides from minerals in the parent rock, especially biotite, is the initial process in evidence. The iron oxides are concentrated in fissures at the weathering front, at the margins of blocks and boulders and adjacent to joint partings. The hydrothermally altered minerals are dissolved and the plagioclases are weathered to clays.

2. Removal of iron and kaolinisation are represented by the appearance of white rinds. These processes are usually achieved in acid reducing solutions, which appear to have leached most of the calcium, iron and sodium and some of the silica and produced the newly formed mass of isotropic to insepic materials (see Brewer 1964, p. 309), mainly kaolinite. Inside this isotropic plasmic material are resistates such as quartz and muscovite {skeleton grains, of Brewer (1964, 1976)}. On the whole, however, kaolinite is dominant.

3. Ferruginisation results from the progressive development of a kaolinitic plasma, and a new porosity plus the destruction of the original textures and structures. Micropores, especially, become the sites of new concentrations of oxides (weak red spots), particularly haematite (Fig. 4), due to the decreased mobility of the solutions in these pores (Didier *et al.* 1983; Tardy & Nahon 1985). This is the origin of the 'mottled clay horizon' typical of profiles developed under seasonally wet and dry climates.

4. The development of nodular structure is related to the removal of oxides and hydroxides by solutions probably emanating from an overlying soil. A new kaolinitic plasma is developed as the oxyhydroxides are removed. The mobility of the materials is governed by the amount of oxyhydroxides: the less oxyhydroxide the more plasmic movement and hence better re-organisation of the soil mass.

5. The removal of oxides and hydroxides requires acid solutions (i.e. those which are poor in carbonates), so that the processes described in paragraphs 1-3 inclusive predate the development of the calcrete and the deposition of the dune calcarenite.

The age of the profile, and the events to which it relates, are mainly problematic. It is clearly younger than the Proterozoic rocks on which it is developed, and predates the calcarenite which, according to Wilson (1991), is Middle and Late Pleistocene in age (maximum c. 700,000 years). But allocating it to an hiatus of some 1500-2000 Ma is neither precise nor informative. The extent of the hiatus can be reduced if two general arguments are accepted. First, although regoliths have survived the passage of ice sheets (see e.g. Fogelman 1985), the profile, which has apparent equivalents at several points along the west coast of Eyre Peninsula (e.g. Point Brown, Point Labatt, Talia), is unlikely to have survived the Early Permian glaciation, which evidently affected most of the present state of South Australia (e.g. Ludbrook 1969), and subsequent erosion; for the regolith has readily been eroded by marine agencies and by gullying. In these terms the regolith under debate is less than 250 Ma old.

Second, the hiatus is further reduced if it is conceded that the regolith is most likely immediately to predate the cover material, that is the calcarenite. This last suggestion assumes that even if the development of the regolith began long before the deposition of the dune limestone, it would have continued to evolve (see e.g. McFarlane 1986; Bourman 1993) up to (and even beyond) being covered. In these terms the young date for the regolith is of the order of 700,000 years, though, because it must have developed over a long period, it ought to be assigned an age range and could reasonably be labelled Plio-Pleistocene.

Broader considerations support this suggestion. First, with what other regoliths might the Point Drummond profile be related? Ferruginous regoliths are known from various parts of South Australia (e.g. Hossfeld 1926[2]; Northcote 1946; Miles 1952; Horwitz & Daily 1958; Campana 1958; Glaessner & Wade 1958; Horwitz 1960; Wopfner 1967; Daily *et al.* 1974; Twidale *et al.* 1976; Wright 1985; Milnes *et al.* 1985; Bourman *et al.* 1987). They have been variously defined and interpreted (see e.g. Bourman 1993 - but see also McFarlane e.g. 1986; Firman 1994). Some, characterised by a sandy or silty A-horizon, a massive, commonly pisolitic, ferruginous horizon overlying a thick bleached zone, have been labelled laterite. Others, consisting of either a ferruginous crust alone, or a crust resting on a thin bleached horizon, have been termed ferricretes (e.g. Lamplugh 1902; Twidale 1976, p. 196-197). The Point Drummond profile does not sit easily with either of these, but is perhaps closer to the ferricrete than to the laterite, particularly if it is considered together with other stratigrapically comparable regoliths such as that exposed at Point Brown. Ferricretes in southern South Australia have been dated by various means, but on Yorke Peninsula (Horwitz & Daily 1958) local stratigraphy indicates a Pliocene age. Equally, occurrences in the interior of Eyre Peninsula have, on stratigraphic grounds, also been attributed to the Tertiary, some being considered Eocene but others clearly Pliocene or post-Pliocene (Rankin & Flint 1991; Flint & Rankin 1991; Flint 1992). Given the Middle-Late Pleistocene age of the overlying

[2] HOSSFELD, P. (1926) The geology of portions of the Counties of Light, Eyre, Sturt and Adelaide. M.Sc. thesis, University of Adelaide, Adelaide (Unpubl).

calcarenite, a later rather than an earlier Tertiary age seems appropriate for the Point Drummond exposure, and on balance a Plio-Pleistocene attribution is in keeping with the available evidence.

Acknowledgments

The authors thank Dr M. J. McFarlane for comments and suggestions during field work and Mr M. J. Wright and two referees for constructive suggestions on an early draft. Professor Molina's work in the University of Adelaide in the period August-December 1992 was made possible by a grant from the Dirección General de Investigación Cientifica y Técnica (DGICYT), 92-176, Ministerio de Educación y Ciencia, Spain.

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